GEOSYNTHETIC-REINFORCED PAVEMENT DESIGN AND ANALYSIS OF ITS PERFORMANCE

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ABSTRACT-

Road and railway stabilization is the use of geosynthetic reinforcing elements to strengthen the ground in order to work on very soft and weak ground in the construction of asphalted or unpaved vehicle roads and rail systems. The geosynthetics increase the performance and design life of highways and railway construction structures in applications such as geogrids, roads, railways, airports and other earthworks with poor ground strength. Geosynthetics offer a much higher value than traditional road construction products and the fast, simple installation process greatly reduces the construction process. On highways, geosynthetics are placed on the weak base floor before the geosynthetic granular substrate is placed.

Key words: Pavement deterioration, geosynthetics, pavement reinforcement, cracks, rutting, durability.

I.INTRODUCTION

A typical flexible pavement system includes four distinct layers: asphalt concrete, base course, subbase, and subgrade. The surface layer is typically asphalt concrete, which is a bituminous hot-mix aggregate obtained from distillation of crude petroleum. The asphalt concrete is underlain by a layer of base course, typically consisting of 0.2 m to 0.3 m of unbound coarse aggregate. An optional subbase layer, which generally involves lower quality crushed aggregate, can be placed under the base course in order to reduce costs or to minimize capillary action under the pavement.

Pavement distress may occur due to either traffic or environmental loads. Traffic loads result from the repetition of wheel loads, which can cause either structural or functional failure. Environmental loads are induced by climatic conditions, such as variations in temperature or moisture in the subgrade, which can cause surface irregularities and structural distress. Cycles of wetting and drying (or freezing and thawing) may cause the breakdown of base course material. Construction practices also affect pavement performance. For example, the use of aggregates with excessive fines may lead to rapid pavement deterioration. Finally, pavement distress is also a function of its maintenance or, more correctly, lack of maintenance (Yoder and Witczak 1975). For example, sealing cracks and joints at proper intervals and maintaining the shoulders improve pavement performance. The various distress mechanisms induced by traffic and environmental loads can be enhanced through the use of geosynthetics. This paper presents an update to the overview presented by Zornberg and Gupta (2010) on the use of geosynthetics for reinforcement of pavements.

Geosynthetics Geosynthetics are an established family of geomaterials used in a wide variety of civil engineering applications. Many polymers (plastics) common to everyday life are found in geosynthetics. The most common are polyolefins and polyester; although rubber, fiberglass, and natural materials are sometimes used. Geosynthetics may be used to function as a separator, filter, planar drain, reinforcement, cushion/protection, and/or as a liquid and gas barrier.

Geosynthetics have been widely used to serve a variety of roles that greatly lead to roadways performing well. These provide isolation, filtration, stabilization, stiffing, drainage, barrier, and safety functions. Any or more of these different features is used in at least six major roadway applications. The applications include migration of reflective cracking in asphalt overlays, isolation, road base stabilization, ground soft subgrade stabilization, and lateral drainage. The American Society for Testing and Materials (ASTM) Committee D35 on geosynthetics has described geosynthetics as planar products made from polymeric materials used with materials related to soil , rock, earth, or other geotechnical engineering as an integral part of a man-made project, structure, or system. Geosynthetics is the term used to describe a variety of polymeric materials used in construction of civil engineering works. The concept is commonly considered to cover eight major categories of goods. These include geotextiles, geogrids, geonets, geomembrane, liners of geosynthetic mud, geofoam, geocells, and geocomposite. The geotextiles and geomembrane are the most common geosynthetics employed. The ASTM (1994) describes geotextiles as permeable textile materials used as an integral part of a civil engineering project, structure, or device in contact with soil, rock, earth, or any other geotechnical substance. Geomembrane is an inherently impermeable membrane, in the shape of a sheet that is commonly used as cut-offs and liners. These are also used to landfill lineups. Geotextiles, as permeable textile materials, are used as an integral part of a civil engineering project, structure or system in contact with soil, rock, earth or any other associated geotechnical material. A geogrid is a polymeric structure, unidirectional or bidirectional, in the form of a manufactured surface, consisting of a normal network of integrally connected elements which can be linked by extrusion, bonding, and whose openings are larger than the constituents and are used in geotechnical, environmental, hydraulic and transport engineering applications. A geonet is a polymeric structure in the form of a manufactured sheet which consists of a regular network of integrally connected overlapping ribs whose openings are typically larger than their constituents. A geocomposite is an engineered polymeric material in the form of manufactured sheets or bars, consisting of at least one geosynthetic portion used in applications for geotechnical environmental and transport engineering.A geomat is a polymeric structure in the form of a manufactured sheet consisting of non-regular networks of fibres , yarns, filaments, tapes or other elements that may be linked thermally or mechanically, and whose openings are larger than their constituents.

II. PROBLEM STATEMENT

High volume traffic pavements transfer their traffic load typically on asphalt or concrete treated surface over a base course layer & distribute the load on subgrade. When the subgrade soil is weak or unable to support adequate traffic loads for long time duration due to either traffic or environmental loads, there will permanent deformation in the pavement. Improvement of load carrying capacity of the conventional unreinforced pavements is costly. Some smart materials can offer low life-cycle cost by improving structural capacity as well as reducing of deformation and thickness of pavement that are construction cost efficient, eco-friendly, beneficial for the community, and useful for engineering purpose [1].

Although in roadway applications comparatively less common, additional geosynthetic functions include: Hydraulic / Gas Barrier: Geosynthetic minimizes cross-plane leakage, ensuring liquid or gaseous containment. Core design properties to fulfill this role include the ones used to define the geosynthetic material's long-term durability. Protection: The geosynthesis creates a barrier above or below other materials (e.g. a geomembrane) to mitigate damage during the placing of overlying materials. Core design properties for quantifying this role include the ones used to describe the geosynthetic material's puncture resistance. Geosindics: A planar, polymeric (synthetic or natural) material used for filtration, drainage, isolation, stabilization, safety, sealing and packaging in contact with the soil / rock and/or any other geotechnical material. Geosynthetics have proved to be among the most versatile, practical, and cost-effective materials for ground modification, adaptation. Their use has spread rapidly into almost every field of geotechnical, marine, coastal and hydraulic engineering of metropolitan cities. Geosynthetics are an existing family of geo-materials used for a wide range of applications in civil engineering. Geosynthetics show a large number of polymers (plastics) essential to daily life. Possible the various forms of geosynthetics [2].

III. TYPE OF FAILURE MODES

During its lifetime, a flexible pavement can experience two different types of failure modes: structural and functional. Structural failure leads to the collapse of the pavement, thereby making it incapable of sustaining the surface loads. Functional failure, on the other hand, renders the pavement incapable of carrying out its intended function, causing discomfort to passengers. Structural failure requires a complete rebuilding of the pavement whereas functional failure can be remediated by maintenance. Pavement distress may occur due to either traffic or environmental loads. Traffic loads result from the repetition of wheel loads, which can cause either structural or functional failure. Environmental loads are induced by climatic conditions, such as variations in temperature or moisture in the subgrade, which can cause surface irregularities and structural weaknesses. Cycles of wetting and drying (or freezing and thawing) cause base course material to breakdown, generating fines in the subgrade and leading to crack development. Construction practices also affect pavement distress conditions. For example, the use of aggregates with excessive fines and inadequate inspection may lead to rapid pavement deterioration. Finally, pavement distress is also a function of maintenance or, more correctly, lack of maintenance (Yoder and Witczak 1975). For example, sealing cracks and joints at proper intervals and maintaining the shoulders help improve pavement performance. Ultimately, a pavement's intended longevity represents a calculated decision on the part of the engineer who has to balance increased initial construction costs against increased maintenance costs during the design process.

Reinforcement function

Typical functions of geosynthetics used in the construction of roadways include reinforcement, separation, filtration, lateral drainage and sealing (Koerner 2005). Geosynthetics used for separation minimize intrusion of subgrade soil into the aggregate base or sub-base. The potential for the mixing of soil layers occurs when the base course is compacted over the subgrade during construction and also during operation of traffic. Additionally, a geosynthetic can perform a filtration function by restricting the movement of soil particles while allowing water to move from the subgrade soil to the coarser adjacent base. In addition, the in-plane drainage function of a geosynthetic can provide lateral movement of water within the plane of the geosynthetic. Finally, geosynthetics can be used to mitigate the propagation of cracks by sealing the asphalt layer when used in the overlay of the pavement.

IV. INSTALLATION OF GEOSYNTHETICS

The key to obtaining optimum performance of a reinforcing interlayer system is correct installation of geosynthetics and asphalt cement tack coat (Marienfeld & Guram, 1999; Carver & Sprague, 2000; Maurer & Malasheskie, 1989). Winkling of geosynthetics and poor tack coat application were the most commonly encountered problems with placing geosynthetics (Maurer & Malasheskie, 1989). Therefore, during construction, the following three critical aspects were seriously conducted:

1. The tack coat was applied at the proper rate and uniformly spread for complete coverage. The typical tack coat application rate was 0.8~1.2 l/m2 . The roughness of the surface, the porosity of the road received slight modification of this application rate in accordance with the experiences of construction crew.

2. Geosynthetics laydown must be smooth, with minimal wrinkling. The laydown operation proceeded in the direction of wheel travel. Stiff bristle brooms were employed to make geosynthetics bond old pavement surface by hand.

Geogrid was demanded to extended a additional length in accordance with 1.0%～1.5% of the original length of geogrid. Namely, one end of geogrid was fixed in place at the beginning point and unrolled, and then jigs were used to hold the other end and extend the geogrid to the demanded length, and also geogrid was fixed with nails at intervals of 1~2 m. 3. For geogrid, transverse paving joint between successive rolls of geogrid was overlapped 300~400 mm, and longitudinal paving joint was overlapped about 100 mm, and for geotextile, at joints, overlapped the geotextile by 250~750 mm. Apply additional tack coat or emulsion uniformly along the overlap seam.

V. GEOSYNTHETICS IN ROAD CONSTRUCTION

Geosynthetics have an assortment of employments from disintegration control to bank fortification to improved subsurface seepage. One of the most widely recognized uses, in any case, is in road construction, especially impermanent roads, for example, construction roads, get to roads and woods ways. These are the advantages of utilizing geosynthetics for these applications. Geotextile to the road infrastructure thanks to the separation function when applied the layers are prevented from mixing with each other [4-8].

Bearing limit: For building the two roads and parking garages, it's significant subgrade is steady with adequate bearing limit. By utilizing geogrids between the subsoil and base course, bearing limit is expanded. The interlocking of the spread soil with the geogrid gives level power move, which serves to expand bearing limit and, by and large, take into consideration base course thickness to be decreased. This strategy additionally makes costly soil trade superfluous [9-15].

Rutting: One of the essential concerns when building unpaved roads on delicate subsoil is rutting and between blending of spread material into the subsoil. By improving burden circulation, geogrids serve to limit both rutting and soil intermixing. A particular task's necessities will direct the determinations of the geogrid required [3].

Power extension: Low extension qualities of a geogrid are required for a fruitful fortification application. In numerous tasks, power assimilation at stretching requires an item with between 2-percent and 5-percent limit. For all the more requesting applications, items with up to 8-percent extension at break are accessible [1].

Establishment power: At long last, it's essential to consider a geogrid's protection from establishment loads. High unique anxieties can negatively affect support while introducing and compacting spread soils and base course materials. To withstand this pressure, a geogrid ought to have thick, solid support bars [2].

VI. GEOSYNTHETICS IN ROADS AND PAVEMENTS

A large variety of detrimental factors affect the service life of roads and pavements including environmental factors, subgrade conditions, traffic loading, utility cuts, road widenings, and aging. These factors contribute to an equally wide variety of pavement conditions and problems which must be addressed in the maintenance or rehabilitation of the pavements, if not dealt with during initial construction. Pavement maintenance treatments are often ineffective and short lived due to their inability to both treat the cause of the problems and renew the existing pavement condition. The main cause of distress in pavements is that they are quite permeable with 30 to 50% of precipitation surface water infiltrating through the pavement, softening and weakening the pavement subgrade and base, accelerating pavement degradation. Existing pavement distress such as surface cracks, rocking joints, and subgrade failures cause the rapid reflection of cracking up through the maintenance treatment. Therefore, the preferred strategy for long-term road and pavement performance is to build in safeguards during initial construction. These performance safeguards include stabilizing the subgrade against moisture intrusion and associated weakening; strengthening road base aggregate without preventing efficient drainage of infiltrated water; and, as a last resort, enhancing the stress absorption and moisture proofing capabilities of selected maintenance treatments. Geosynthetics are the most costeffective tools for safeguarding roads and pavements in these ways.

SUBGRADE SEPARATION AND STABILIZATION

Introduction to the Problem Temporary roads used for hauling and access roads that are subject to low volumes of traffic are often constructed without asphalt or cement concrete surfacing. In these cases, a layer of aggregate is placed on the prepared subgrade of these roads to improve their load carrying capacity. Problems are usually encountered when the subgrade consists of soft clays, silts and organic soils. This type of subgrade is often unable to adequately support traffic loads and must be improved.

Stabilization

For larger rut depths, more strain is induced in the geosynthetic. Thus the stiffness properties of the geosynthetic are essential. A considerable reduction in aggregate thickness is possible by the use of a geosynthetic having a high modulus in the direction perpendicular to the road centerline; however, the benefits of the geosynthetic are not wholly dependent on the membrane action achieved with a stiff geosynthetic. Lateral restraint produced by the interaction between the geosynthetic and the aggregate is equally important. The following general conclusions can be drawn relating to a typical road base.

• A geosynthetic element that functions primarily as a separator (typically when the subgrade CBR ≥ 3) will increase the allowable bearing capacity of the subgrade by 40 to 50 percent. (separation geotextiles)

• A geosynthetic element that functions primarily to provide confinement of the aggregate and lateral restraint to the subgrade (typically when the subgrade CBR < 3) will both increase the allowable bearing capacity of the subgrade and provide an improved load distribution ratio in the aggregate. The combined benefits can enhance load carrying capacity of the road by well over 50 percent. (stabilization geogrids and geotextiles).

BASE REINFORCEMENT

Introduction to the Problem Permanent roads carry larger traffic volumes and typically have asphalt or portland cement concrete surfacing over a base layer of aggregate. The combined surface and base layers act together to support and distribute traffic loading to the subgrade. Problems are usually encountered when the subgrade consists of soft clays, silts and organic soils. This type of subgrade is often water sensitive and, when wet, unable to adequately support traffic loads. If unimproved, the subgrade will mix with the road base aggregate – degrading the road structure - whenever the subgrade gets wet.

VII. CONCLUSIONS AND RECOMMENDATION

The available literature involving field, laboratory and numerical study results demonstrate that Geosynthetics materials can use separation, reinforcement, filtration, drainage, and containment functions of the pavement. Pavement performance can be improved by placing geosynthetics at the upper one-third of the base course-layer. Geogrids helps in less accumulated permanent deformation in the subgrade layer by redistributing the traffic load over a wide area on the subgrade. Approximately half of the thickness reduction resulting from geogrid reinforcement is possible in clay subgrade by inter locking effect when it is placed in a convex shape. Modified AASHTO design results that about 20% to 40%base course reduction is possible using geogrid in pavement design, with greater percentage reduction for stronger subgrade materials. Future research works are needed for designing the geogrid reinforcement pavement by Mechanistic-Empirical design method and efforts are needed to establish the guideline for placement of geogrid in the pavement.

Geotextiles are powerful instruments in the civil engineer 's hands and have proved to solve a variety of geotechnical issues. With the availability of a variety of products with different characteristics, the design engineer needs to be aware not only of the application possibilities but also more specifically the reason why he uses the geotextile and the functional properties of the governing geotextile to fulfill these functions. The creation and development of geotextiles focused on sound engineering concepts would benefit both consumer and business long-term purpose. Effectiveness of geotextiles relies on the quality and proper installation of the cloth. Geotextiles are a cost-effective means of achieving proper irrigation and subgrade stabilisation. Thus it can be inferred that the geotextiles benefit from careful deployment, handling and maintenance in road building. In separation uses, also, permeability should always be considered to allow moisture to move freely through the system. This prevents excessive hydrostatic stresses that cause soil failure.

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